Effects of Temperature and Salinity on Larval Growth Rates and Dispersal Potential of the Introduced Bivalve, the Varnish Clam (*Nuttallia obscurata*), in Coastal British Columbia

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Abstract

We determined the influence of temperature and salinity on larval varnish clam growth rates, in order to establish the tolerance levels of this recently introduced species. Adult varnish clams were spawned in the laboratory during their natural reproductive season and the larvae reared at 9, 15 and 20°C and 10, 15 and 20 ppt. Shell growth was measured twice weekly until the larvae either metamorphosed or died. The highest growth rates occurred in the 20°C and 20 ppt treatments. Time-to-metamorphosis ranged from three to eight weeks, with higher temperatures and salinities resulting in a shorter planktonic phase. Larvae reared at 9°C, 10 and 15 ppt grew slowly and survived for a minimum of one month but did not reach metamorphosis. These results indicate that varnish clam larvae have a wide range of salinity and temperature tolerances, but grow optimally at warmer temperatures and higher salinities. The high variability in time-to-metamorphosis, and the potentially long planktonic phase, has important implications for dispersal and geographical range expansion in the Georgia Basin and Puget Sound.

Introduction

The varnish clam (*Nuttallia obscurata*) first appeared in the Strait of Georgia (SOG) in 1991, spread rapidly throughout the SOG and is currently expanding northward in British Columbia (BC). Its current geographical limits are the Brooks Peninsula on the west coast of Vancouver Island (WCVI) to the north, and Alsea Bay, Oregon, to the south. Originally a native of Korea, China and southern Japan, this species is suspected to have been introduced through ballast water disposal in Vancouver Harbour (Gillespie et al. 1999). The varnish clam is found intertidally in sand and gravel substrates (Heath 1998), most abundantly in the high intertidal zone. It is often found with other species such as the manila clam (*Venerupis philippinarum*) and the Pacific littleneck clam (*Protothaca staminea*). Varnish clams in the northwestern Pacific are broadcast spawners with planktonic larvae (Miyawaki and Sekiguchi 1999); however, little is known about its life history or its dispersal potential in the northeastern Pacific. The objectives of this study were: (1) to determine the tolerance of varnish clam larvae to a range of temperatures and salinities; and (2) to investigate varnish clam larval dispersal and invasion success in light of local oceanographic currents and local bivalve life histories.

Methods

Adult varnish clams were collected from Barkley Sound on the WCVI (Figure 1). Clams were spawned in the laboratory during their natural reproductive season using standard bivalve spawning techniques (Loosanoff and Davis 1963). The fertilized eggs were incubated at ambient temperature (15°C) and salinity (30 ppt) until they reached the d-stage (after approximately 48 hours). The larvae were then distributed equally among the experimental treatments and reared at 9, 15 and 20°C at ambient salinity, and 10, 15 and 20 ppt at ambient temperature. Shell growth was measured twice weekly until the larvae either metamorphosed or died. Metamorphosis was defined as the point at which the velum was lost and only a foot was present, indicating a switch from planktonic to benthic existence.

Results and Discussion

In the temperature treatments, larval growth rates were significantly different from one another, with larvae in the 20°C treatment growing significantly faster than the other two treatments by day 5 (Figure 2). Larval growth rates were also significantly different in the salinity treatments, with the larvae in the 20 ppt culture being significantly larger than the other two by day 19 (Figure 3). The highest growth rates occurred in the 20°C and 20 ppt treatments. Larvae reared at 9°C, 10 and 15 ppt grew slowly and survived for a minimum of one month but did not reach metamorphosis. The youngest age at settlement observed was 18 days in the 20°C treatment, and the oldest larvae that still possessed a velum (i.e. still planktonic) was 59 days in the 10°C treatment. This yields a time-to-metamorphosis ranging from three to eight weeks, with higher temperatures and salinities resulting in a shorter planktonic phase.

Compared to local bivalves the varnish clam does not appear to have a broader temperature or salinity tolerance range (Table 1); however, the planktonic duration is longer, allowing for greater dispersal potential. In regards to the timing and duration of spawning, the varnish clam does not appear to have an advantage over local species by spawning earlier or for a longer period (Table 2).

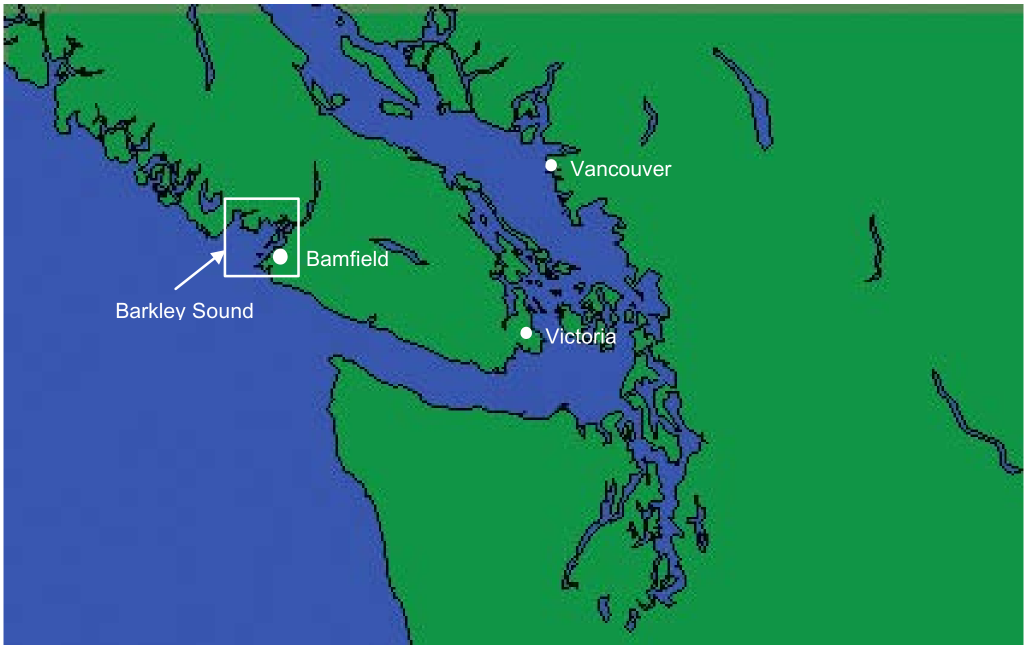

Figure 1. Region of study—Barkley Sound, west coast of Vancouver Island.

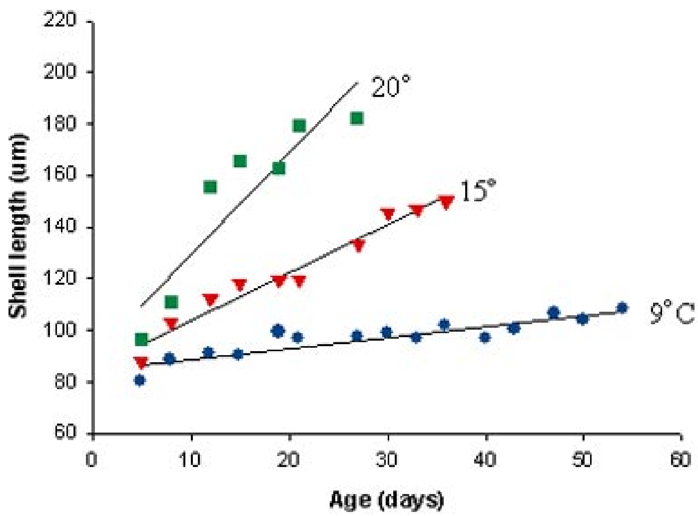

Figure 2. Varnish clam larval growth rates in temperature treatments of 9, 15 and 20°C.

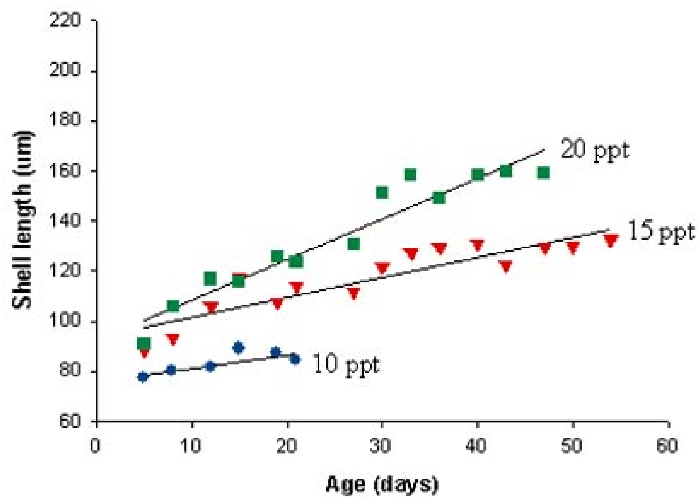

Figure 3. Varnish clam larval growth rates in salinity treatments of 10, 15 and 20 ppt.

Table 1. Optimum and tolerance levels of temperature and salinity and planktonic duration for selected local bivalve species.

Species	Temp °C (optimum)	Sal ppt (optimum)	Temp °C (tolerance)	Sal ppt (tolerance)	Planktonic duration
Varnish clam	20	31	10-25	10-31	3-8 wks
Manila clam	23-24	20-30	10-30	10-15	2-4 wks
Littleneck clam	10-15	27-32			3-4 wks
Mussel (*Mytilus sp*)	15-20	28-40	8-18	28-40	4 d – 3 wks
Japanese oyster	18-23	11-32			16 d – 4 wks
Softshell clam	17-23		10-22	5-32	2 – 3 wks

Table 2. Spawning periods for local bivalve species.

Species	Apr	May	Jun	Jul	Aug	Sept	Oct
Varnish clam							
Manila clam							
Littleneck clam							
Mussel (*Mytilus sp*)							
Japanese oyster							
Softshell clam							

The general surface circulation patterns, during the summer along the northwest Pacific coast, are shown in Figure 4. These flow patterns would facilitate the dispersal of varnish clam larvae, originating from Vancouver Harbour, throughout their entire geographic range. In this region, average current flows during the summer months are approximately 20 cm/s in Johnstone Strait, 10-20 cm/s and up to 40 cm/s (early summer) in Juan de Fuca Strait, and 10 cm/s up to 50 cm/s for the WCVI (Thomson 1982). If larvae behave as passive particles and lack vertical migratory behaviour, at current speeds of 10 cm/s they could travel approximately 8.6 km/day, or 180 km in three weeks, and 516 km in eight weeks. In currents of 20 cm/s this range increases to 378 km in three weeks (Figure 5). Under these conditions the larvae have the ability to disperse throughout their entire geographic range at low current speeds in one reproductive season.

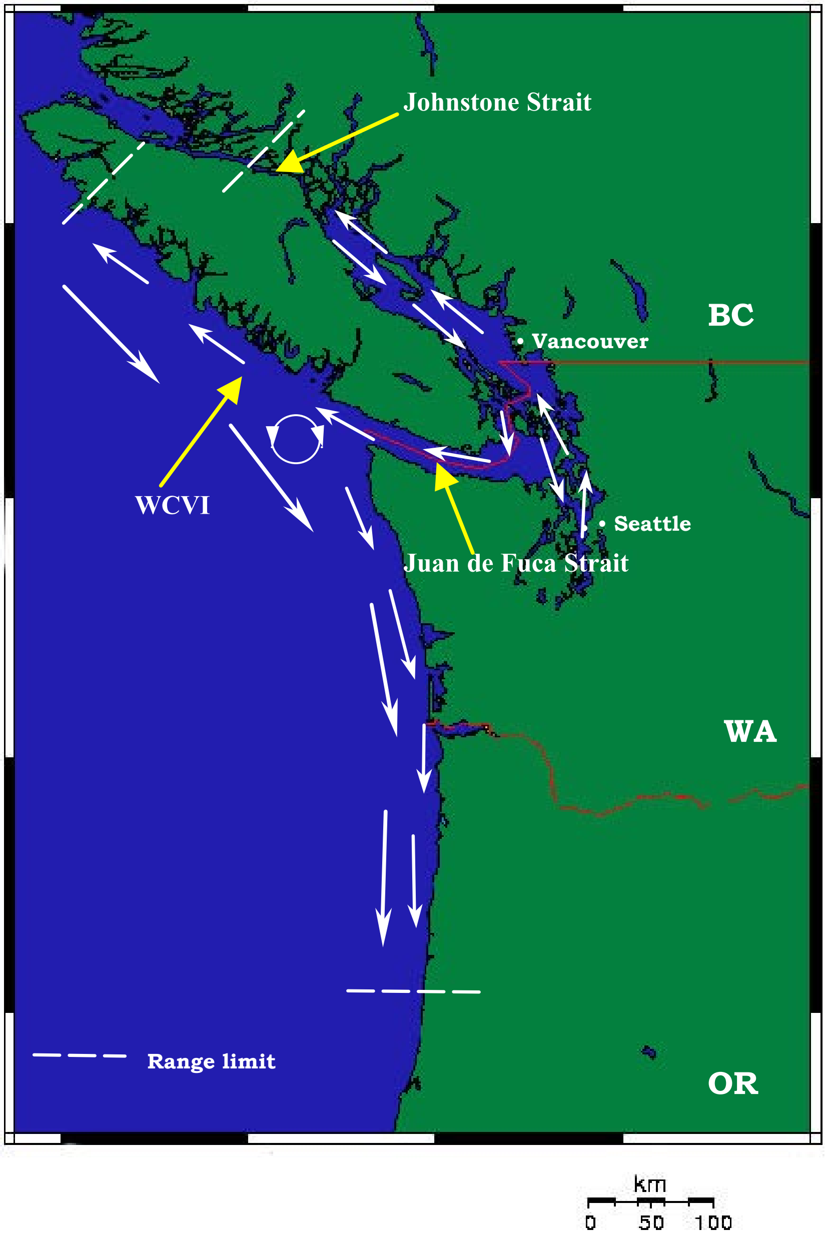

Figure 4. General oceanographic surface circulation pattern for spring and early summer in the Georgia Basin/Puget Sound and outer coastal regions. Arrows represent current direction only.

These results indicate that varnish clam larvae can survive over a wide range of salinities and temperatures, but are not more tolerant than native bivalve species. Although there appears to be no obvious advantage in the timing or duration of varnish clam spawning, their potentially long planktonic phase allows for greater dispersal potential. This long planktonic duration, combined with local current regimes, may have contributed to the rapid dispersal and establishment of this species in the Pacific Northwest.

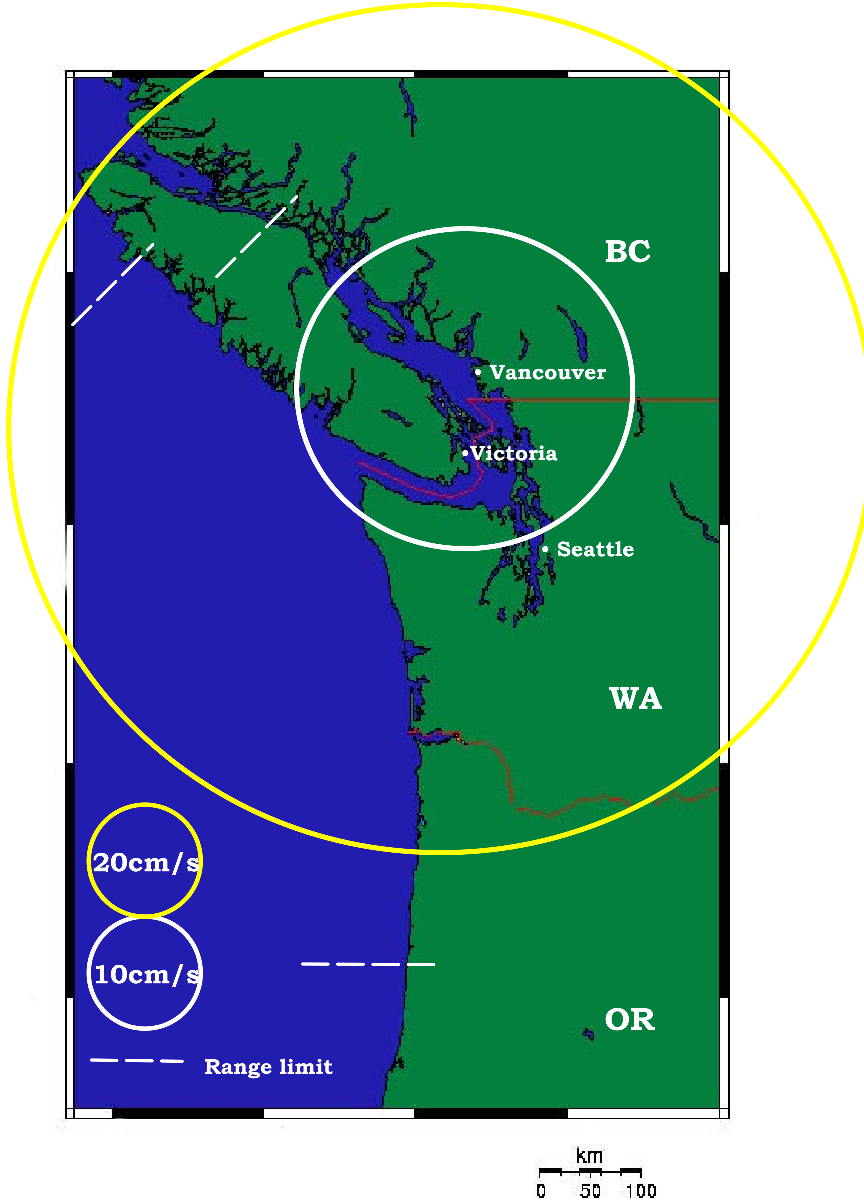

Figure 5. Dispersal potential of varnish clam larvae seeded in Vancouver Harbour assuming passive dispersal via oceanographic currents and no migratory behaviour. Circles represent potential dispersal in 3 weeks at 10 cm/s (white circle, with radius approximately 180 km) and 20 cm/s (yellow circle, with radius approximately 378 km).

References

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